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ENGLISH TRANSLATION OF
JAPANESE PATENT APPLICATION NO. 11-328646

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Attached is a full English translation of Japanese Patent Application No. 11-328646, the Japanese version of which was filed with an Information Disclosure Statement (IDS) on August 15, 2001, along with an English abstract thereof. Since the Japanese version of this reference was properly filed, with the $180.00 fee and an English Abstract, on August 15, 2001, no additional fees are required.

Respectfully submitted,

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TITLE OF THE INVENTION

MAGNETIC RECORDING MEDIUM

ABSTRACT

The present invention is directed to provide a high density magnetic recording medium with remarkable reduction of medium noises.

MEANS TO RESOLVE PROBLEMS

The present invention is characterized in that there is provided a magnetic recording medium having a magnetic recording film formed on a nonmagnetic substrate through a ground layer wherein said magnetic recording film comprises a plurality of magnetic layers and an intermediate layer formed between each magnetic layer, said intermediate layer being an intermediate layer comprising the material whose crystal structure is of B2 or an intermediate layer comprising Ru.

CLAIM

What is claimed is:

1. A magnetic recording medium having a magnetic recording film formed on a nonmagnetic substrate through a ground layer wherein said magnetic recording film comprises a plurality of magnetic layers and an intermediate layer formed between each magnetic layer, said intermediate layer being an intermediate

layer comprising the material whose crystal structure is of B2 or an intermediate layer comprising Ru.

2. A magnetic recording medium as claimed in claim 1 wherein the material of said intermediate layer having the structure of B2 is comprised of one type selected from groups comprising NiAl, NiAlRu, NiAlNd, NiAlCr, NiAlPt and NiAlPd.

3. A magnetic recording medium as claimed in claim 1 or 2 wherein the film thickness of said intermediate layer is 3-30Å.

4. A magnetic recording medium as claimed in claim 1 or 2 wherein the film thickness of said intermediate layer is 3-20Å.

5. A magnetic recording medium as claimed in claim 1,2, 3 or 4 wherein said ground layer comprises Cr or Cr alloy.

6. A magnetic recording medium as claimed in claim 1,2,3,4 or 5 wherein a seed layer comprising the material whose crystal structure is of B2 is formed on said nonmagnetic substrate, said magnetic recording film being formed on said seed layer through said ground layer.

7. A magnetic recording medium as claimed in claim 6 wherein the material of said seed layer is one type selected from groups comprising NiAl, NiAlRu, NiAlNd, NiAlCr, NiAlPt and NiAlPd.

8. A magnetic recording medium as claimed in claim 1,2,3,4 5,6 or 7 wherein said magnetic layer comprises Co family alloy.

9. A magnetic recording medium as claimed in claim 8 wherein said Co family alloy includes CoCrPt alloy or CoCrTaPt one.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

FIELD OF THE TECHNOLOGY

The present invention relates to a magnetic recording medium adapted to a recording medium for a hard disk device.

[0002]

THE CONVENTIONAL TECHNOLOGY

The recent high density recording by a magnetic recording medium results in requiring a low noise medium. The conventional method of reducing medium noises was such that a magnetic recording film was directed to be of a multiple layer structure achieved by forming an intermediate layer between each magnetic layer to reduce the magnetic coupling between a plurality of magnetic layers and each magnetic layer. This is disclosed in Japanese Patent Application Laid-Open No. 63-146219 and IEEE TRANSACTIONS ON MAGNETICS, 26(5), 2700(1990). Also, the use of NiAl having a B2 structure as a ground layer to achieve high coercive force for high density recording is disclosed in IEEE TRANSACTIONS ON MAGNETICS, 30(6), 3951(1994) and European Patent Publication No.704839.

[0003]

The use of Al_2O_3, SiO_2 or Cr film as an intermediate layer for a magnetic recording medium having said multiple-structured magnetic recording film has been considered in said Japanese Patent Application Laid-Open No. 63-146219 to achieve the noise reduction. However, this consideration is inadequate in terms of reducing noises when using a GMR head in the future. Also,

NiAl has been considered for the use as a ground layer according to the European Paten Publication 704839, but a consideration has not be given to that a magnetic recording film should be of a multiple layer structure comprising a plurality of magnetic layers and an intermediate layer to reduce the magnetic coupling disposed between each magnetic layer.

[0004]

PROBLEMS TO BE RESOLVED IN THE PRESENT INVENTION

The object of the present invention is to provide a magnetic recording medium enabling the high density recording and reproducing in which medium noises are remarkably reduced.

[0005]

MEANS TO RESOLVE PROBLEMS

To resolve said problems, the present invention is directed to provide a magnetic recording medium having a magnetic recording film formed on a nonmagnetic substrate through a ground layer wherein said magnetic recording film comprises a plurality of magnetic layers and an intermediate layer formed between each magnetic layer, said intermediate layer being an intermediate layer comprising the material whose crystal structure is of B2 or an intermediate layer comprising Ru.

[0006]

According to the present invention, the magnetic recording film can be either of the construction wherein a two-layered magnetic layer and an intermediate layer comprising the material whose crystal structure is of B2 or of the

construction wherein a magnetic layer comprising more than three layers and an intermediate layer comprising the material whose structure is of B2 are formed between each magnetic layer.

[0007]

As the material for the intermediate layer having said B2 structure, one type out of NiAl, NiAlRu, NiAlNd, NiAlCr, NiAlPt and NiAlPd can be used.

[0008]

Also, the magnetic recording film of the present invention can be either of the construction wherein a two-layered magnetic layer and an intermediate layer comprising Ru are formed between each magnetic layer or of the construction wherein a magnetic layer comprising more than three layers and an intermediate layer comprising Ru are formed between each magnetic layer. This intermediate layer comprising Ru is preferably of the close-packed hexagonal structure.

[0009]

The film thickness of the intermediate layer comprising the material having B2 structure or the one comprising Ru is preferably more than 3Å, or 5Å and further, less than 50Å or 30Å. The film thickness of the intermediate layer which is extremely thin provides no adequate noise reduction efficiency. The film thickness of the intermediate layer which is extremely thick results in having no noise reduction efficiency. In addition, the coercive force is deteriorated to a great extent or such characteristics as the resolution required for the magnetic medium and PW50 (a half-width of the isolated

reproduction wave) are degenerated. The foregoing results show that the film thickness of the intermediate layer is preferably 3-30Å, especially 3-20Å. However, the film thickness of each intermediate layer when forming said intermediate layer between each magnetic layer with more than three layers is preferably 3-30Å, especially 3-20Å.

[0010]

According to the present invention, a substrate comprising aluminum alloy, glass or crystallized glass can be for the use with a nonmagnetic substrate. Cr or Cr alloy can be employed as a ground layer of the present invention. CrMo, CrW, CrTi, CrV or CrMn can be used as Cr alloy.

[0011]

Also, according to the present invention, when using a nonmagnetic substrate comprising said glass or crystallized glass, it is specifically preferred that a seed layer comprising the material whose crystal structure is of B2 is formed on said substrate and that said magnetic recording film is formed on said seed layer through said ground layer.

[0012]

NiAl, NiAlRu, NiAlNd, NiAlCr, NiAlPt or NiAlPd can be used as the B2-structured material for said seed layer.

[0013]

Said seed layer is formed on the nonmagnetic substrate comprising the said glass or crystallized glass. This makes it possible to control not only growth of the particle and film of Cr or Cr alloy ground layer on the seed layer but also growth

of the particle and film of the magnetic recording film formed on said ground layer.

[0014]

According to the present invention, a magnetic layer comprising a magnetic recording film is preferably of Co family alloy. For example, a magnetic layer which has Co as the principal ingredient and which comprises Co family alloy including at least Cr and Pt can be selected for the use in the magnetic layer of the present invention. Moreover, a magnetic layer made up of Co family alloy including at least one type selected from the group comprising Ta, Mo, W, Nb, V, Zr, B and Ti can be used. More specifically, a magnetic layer comprising CoCrPt alloy or CoCrTaPt one can be selected for the use in said magnetic layer.

[0015]

The magnetic recording medium according to the present invention can be provided by further forming a protection film and lubricant film in order on said magnetic recording film. For example, the carbon family material can be used for the protection film and a perfluoropolyether family lubricant, for the lubricant film.

[0016]

EMBODIMENTS [Example 1 (Embodiment) and Example 2 (Comparison Example]

The deposition was carried out as follows by applying bias voltage of -200V to a substrate under Ar atmosphere of 5mTorr and substrate temperature of 220°C after exhausting air from

a sputtering chamber up to the vacuum reaching degree of $1x10^{-6}$ Torr.

[0017]

A CrMo layer with the thickness of 300Å was formed by a magnetron sputtering method to be a ground layer on a NiP/Al substrate to which the texture treatment was made using the target comprising $Cr_{85}Mo_{15}$ (each ingredient is represented by atomic %).

[0018]

Next, a first magnetic layer with the thickness of 110Å comprising $Co_{71}Cr_{17}Ta_5Pt_7$ each of which ingredient volume is represented by atomic % was formed on said CrMo layer by said magnetron sputtering method and then, a NiAlRu intermediate layer with the thickness of 5-70Å was formed on said first magnetic layer using the target of $NI_{45}Al_{50}Ru_5$ each of which ingredient volume is represented by atomic %. Furthermore, after forming on said intermediate layer by the same method as above, a second magnetic layer comprising $Co_{71}Cr_{17}Ta_5Pt_7$ with the thickness of 110Å, a carbon family protection film and lubricant film were formed in order on said second magnetic layer. This resulted in being a sample in Example 1 showing the magnetic recording medium of the present invention. Said NiAlRu intermediate layer was determined to be of B2 structure by X-Ray diffraction method.

[0019]

Also, a magnetic recording medium having the same structure as the sample in Example 1 was formed by the same method

as stated above except that a Cr intermediate layer with the thickness of 5-70Å was formed as an intermediate layer. This resulted in being a sample in Example 2.

[0020]

Fig. 1 shows changes of the signal output ratio to the total noise (S/Nt) resulted when changing within the range of 0-50Å the film thickness of the NiAlRu intermediate layer in Example 1 and that of the Cr intermediate layer in Example 2. In the case of the NiAlRu intermediate layer, the S/Nt is found to improve up to the range of 30Å when increasing the film thickness from zero. Also, it is evident that the S/Nt improves compared with the case of the Cr intermediate layer.

[0021]

Fig. 2 shows changes of the coercive force (Hs) resulted when changing within the range of 0-70Å the film thickness of the NiAlRu intermediate layer in Example 1 and that of the Cr intermediate layer in Example 2. The deterioration of the coercive force (Hs) in the case of NiAlRu intermediate layer is found to be less than that in the case of the Cr intermediate layer.

[0022]

The foregoing consideration results in making it possible to have a magnetic recording film of the present invention comprised of Co family alloy magnetic layer, B2-structured NiAlRu intermediate layer and Co family alloy magnetic layer. Furthermore, it makes it possible to have the film thickness of said B2-structured NiAlRu intermediate layer determined to

be selected within the range of 3-30Å, especially, 3-20Å. This achieves the remarkable improvement of the S/Nt whose value is greater than that in the case of the Cr intermediate layer. This selection reduces the coercive force (Hc) to some extent, but not so great as to cause an impediment to achieving the high density recording. In the case of the Cr intermediate layer, not only the S/Nt improvement is less expected but also the coercive force (Hs) is significantly reduced.

[0023]

Table 1 shows electromagnetic conversion characteristics resulted from the film thickness of 15Å in the NiAlRu intermediate layer which is significant in improving the S/Nt. It is evident from the film thickness of 15Å of the NiAlRu intermediate layer that not only N media (medium noise), S/Nt, and S/Nm (signal output ratio to the medium noise) but also the resolution as well as PW50 (half-width of the isolated reproduction wave) are far more excellent than those in the case of using Cr intermediate layer.

[0024]

[Example 3 (Embodiment) and Example 4 (Comparison Example)]

The deposition was carried out as follows without applying bias voltage to the substrate under Ar atmosphere of 5mTorr and substrate temperature of 270°C after exhausting air from the sputtering chamber up to the vacuum reaching degree of $1x10^{-6}$ Torr.

[0025]

A NiAl seed layer with the thickness of 500Å was first

formed on a nonmagnetic substrate comprising alminosilicate glass by a magnetron sputtering method using the target comprising the B2-structured $Ni_{50}Al_{50}$ and then, a Cr layer with the film thickness of 300Å was formed as a ground layer.

[0026]

Next, a first magnetic layer with the thickness of 110Å comprising $Co_{71}Cr_{17}Ta_4Pt_8$ each of which ingredient volume is represented by atomic % was formed on said Cr layer by said magnetron sputtering method and then, a Ru intermediate layer with the film thickness of 5-50Å was formed on said first magnetic layer using the Ru target. Furthermore, after forming on said Ru intermediate layer by the same method as above a second magnetic layer comprising $Co_{71}Cr_{17}Ta_4Pt_8$ with the thickness of 110Å, a carbon family protection film and lubricant film were formed in order on said second magnetic layer. This resulted in being a sample in Example 3 showing the magnetic recording medium of the present invention. By X-Ray diffraction method, said NiAlRu seed layer and said Ru intermediate layer were determined to be of B2 structured-NiAl comprised of $Ni_{50}Al_{50}$ and of the close-packed hexagonal structure respectively.

[0027]

Also, a magnetic recording medium having the same construction as the sample in Example 3 was formed by the same method as stated above except that a Cr intermediate layer with the thickness of 220Å was formed as an intermediate layer. This resulted in being a sample in Example 4.

[0028]

Fig. 3 shows changes of the signal output ratio to the total noise (S/Nt) resulted when changing within the range of 0-50Å the film thickness of the Ru intermediate layer in Example 3 and that of the Cr intermediate layer in Example 4. In the case of the Ru intermediate layer, the S/Nt is found to improve up to the range of 30Å when increasing the film thickness from zero. Also, it is evident that the S/Nt improves compared to the case of the Cr intermediate layer.

[0029]

Fig. 4 shows changes of the coercive force (Hs) resulted when changing within the range of 0-50 Å the film thickness of the Ru intermediate layer in Example 3 and that of the Cr intermediate layer in Example 4. The deterioration of the coercive force (Hs) in the case of Ru intermediate layer is found to be less than that in the case of the Cr intermediate layer.

[0030]

The foregoing consideration results in making it possible to have the magnetic recording film of the present invention comprised of Co family alloy magnetic layer, Ru intermediate layer and Co family alloy magnetic layer. Furthermore, the appropriate selection of the film thickness of said Ru intermediate layer within the range of 3-30Å, especially, 3-20Å, achieves the remarkable improvement of the S/Nt whose value is greater than that in the case of the Cr intermediate layer. This selection reduces the coercive force (Hc) to some extent, but not so great as to cause an impediment to achieving the high density recording. In the case of the Cr intermediate layer,

not only the S/Nt improvement is less expected but also the coercive force (Hs) is significantly reduced.

[0031]

Table 1 shows electromagnetic conversion characteristics resulted from the film thickness of 10Å in the Ru intermediate layer which is significant in improving the S/Nt. It is evident that the Ru intermediate layer with film thickness of 10Å is far more excellent than in the case of using a Cr intermediate layer in respect of not only N media (medium noise), S/Nt and S/Nm (signal output ratio to the medium noise) but also the resolution as well as PW50 (half-width of the isolated reproduction wave).

[0032]

[Example 5 (Embodiment) and Example 6 (Comparison Example)]

The deposition was carried out as follows without applying bias voltage to a substrate under Ar atmosphere of 5mTorr and substrate temperature of 270°C after exhausting air from the sputtering chamber up to the vacuum reaching degree of 1×10^{-6} Torr.

[0033]

A NiAl seed layer with the thickness of 500Å was first formed on a nonmagnetic substrate comprising alminnosilicate glass by a magnetron sputtering method using the target comprising the B2-structured $Ni_{50}Al_{50}$ each of which ingredient volume is represented by atomic% and then, a $Cr_{85}Mo_{15}$ layer (each ingredient is represented by atomic%) whose film thickness is 100Å was formed as a ground layer.

[0034]

Next, a first magnetic layer with the thickness of 110Å comprising $Co_{68}Cr_{20}Ta_2Pt_{10}$ wherein each ingredient volume is represented by atomic % was formed on said CrMo layer by said magnetron sputtering method and then, a Ru intermediate layer with the film thickness of 10Å with which the maximum S/Nt value was obtained was formed on said first magnetic layer using the Ru target. Furthermore, after forming on said intermediate layer by the same method as above a second magnetic layer comprising $Co_{68}Cr_{20}Ta_2Pt_{10}$ with the thickness of 110Å, a carbon family protection film and lubricant film were formed in order on said second magnetic layer. This resulted in being a sample in Example 5 showing the magnetic recording medium of the present invention. By X-Ray diffraction method, said seed layer and said Ru intermediate layer were determined to be of B2 structure made up of $Ni_{50}Al_{50}$ and of the close-packed hexagonal structure respectively.

[0035]

Also, a magnetic recording medium having the same construction as the sample in Example 5 in respect of a substrate, seed layer and ground layer was formed by the same method as stated above except that a magnetic recording film comprising a $Co_{68}Cr_{20}Ta_2Pt_{10}$ magnetic layer (single layer film) with the thickness of 220Å was formed as a magnetic recording film on the ground layer. This resulted in being a sample in Example 6.

[0036]

The use of the B2-structured NiAl for a seed layer makes it possible to have a magnetic recording film comprised of Co family alloy magnetic layer, Ru intermediate layer and Co family alloy magnetic layer. Furthermore, the appropriate selection of the film thickness of said Ru intermediate layer within the range of 3-30Å, especially 3-20Å, achieves the remarkable improvement of the S/Nt. This selection reduces the coercive force (Hc) to some extent, but not so great as to cause an impediment to achieving the high density recording.

[0037]

Table 1 shows Hc (Oe) and magnetic conversion characteristics resulted from the film thickness of 10Å in the Ru intermediate layer which is significant in improving the S/Nt. It is evident from the film thickness of 10Å of the Ru intermediate layer that the magnetic recording medium with the structure of having a plurality of layers is far more excellent than in the case of using a magnetic recording film comprising one magnetic layer (single layer film) in respect of not only N media (medium noise), S/Nt and S/Nm (signal output ratio to the medium noise) but also the resolution as well as PW50 (a half-width of the isolated reproduction wave).

[0038]

Table 1

	Resolution (%)	PW50 (nsec)	O/W (-dB)	Nmedia (mV^2)	S/Nt (dB)	S/Nm (dB)	Hc (0e)
Example1	74.13	18.41	35.6	2.53	23.6	28.6	
Example2	72.46	18.85	36.8	4.17	20.1	26.3	
Example3	73.13	24.57	38.5	23.86	17.4	19.3	
Example4	70.05	26.10	41.5	24.50	15.8	17.7	

Example5	62.10	18.95	37.05	16.72	23.06	26.71	2500
Example6	61.20	19.10	35.86	44.90	20.49	22.10	2600

[0039]

[Example 7 (Embodiment) and Example 8 (Comparison Example)]

The deposition was carried out as follows without applying bias voltage to the substrate under Ar atmosphere of 5mTorr and substrate temperature of 270°C after exhausting air from the sputtering chamber up to the vacuum reaching degree of 1×10^{-6} Torr.

[0040]

A NiAl seed layer with the thickness of 500Å was first formed on a nonmagnetic substrate comprising alminosilicate glass by a magnetron sputtering method using the target comprising the B2-structured $Ni_{50}Al_{50}$ each of which ingredient volume is represented by atomic% and then, a $Cr_{85}Mo_{15}$layer each of which ingredient is represented by atomic% with the film thickness of 300Å was formed as a ground layer.

[0041]

Next, a first magnetic layer with the thickness of 110Å comprising $Co_{79}Cr_{15}Ta_3Pt_3$ each of which ingredient volume is represented by atomic% was formed on said Cr layer by said magnetron sputtering method and then, a NiAl intermediate layer with the film thickness of 5-108Å was formed on said first magnetic layer using the $Ni_{50}Al_{50}$ target. Furthermore, after forming on said intermediate layer by the same method as above a second magnetic layer comprising $Co_{79}Cr_{15}Ta_3Pt_3$ with the thickness of 110Å, a carbon family protection film and lubricant

film were formed in order on said second magnetic layer. This resulted in being a sample in Example 7 showing the magnetic recording medium of the present invention. By X-Ray diffraction method, said NiAl seed layer and NiAl intermediate layer were determined to be of B2 structure made up of $Ni_{50}Al_{50}$.

[0042]

Also, a magnetic recording medium having the same structure as that of the sample in Example 7 was formed by the same method as stated above except that an intermediate layer with the film thickness of 5-75Å was formed as an intermediate layer comprising Cr. This resulted in being a sample in Example 8.

[0043]

Fig. 5 shows changes in standardized medium noises resulted when changing the film thickness of a NiAl intermediate layer in Example 7 and that of a Cr intermediate layer in Example 8. A horizontal axis shows a magnetizing transition number x10^3 (kFCI) per inch. A vertical (?) axis shows values given by having standardized by the output signal portion in 20kFCI the medium output noise portion in each frequency measured by a GUZIK-made read-write tester and Hewlett-Packard-made spectrum analyzer to erase the difference caused by Mrt (the residual magnetization by the film thickness).

[0044]

The use of the NiAl intermediate layer is found to have the medium noise significantly reduced with the film thickness of being within the range of 3-30Å, especially 3-20Å. In

addition, the medium noise is proved to be remarkably reduced if the film thickness of the intermediate layer is within the range of 3-30Å, especially 3-20Å.

[0045]

ADVANTAGES OF THE PRESENT INVENTION

The present invention relates to a magnetic recording medium having a magnetic recording film formed on a nonmagnetic substrate through a ground layer wherein said magnetic recording film comprises a plurality of magnetic layers and an intermediate layer formed between each magnetic layer, said intermediate layer being an intermediate layer comprising the material whose crystal structure is of B2 or an intermediate layer comprising Ru. This achieves the advantage to have the medium noise significantly reduced.

[0046]

Also, when using a nonmagnetic substrate comprising glass or crystallized glass, a seed layer comprising the material whose crystal structure is of B2 is formed on said substrate and said magnetic recording film with the structure of having a plurality of layers is formed on said seed layer through said ground layer. This achieves the advantage to have the medium noise remarkably reduced.

BRIEF DESCRIPTION OF DRAWINGS

Fig.1 is a graph showing the relation between S/Nt and each film thickness of the NiAlRu intermediate layer in Example 1 and Cr intermediate layer in Example 2.

Fig.2 is a graph showing the relation between Hc and each film thickness of the NiAlRu intermediate layer in Example 1 and Cr intermediate layer in Example 2.

Fig.3 is a graph showing the relation between S/Nt and each film thickness of the Ru intermediate layer in Example 3 and Cr intermediate layer in Example 4

Fig. 4 is a graph showing the relation between Hc and each film thickness of the Ru intermediate layer in Example 3 and Cr intermediate layer in Example 4.

Fig. 5 is a graph showing the relation between the standardized noise and each film thickness of the NiAl intermediate layer in Example 7 and Cr intermediate layer in Example 8.

FIGURES 1-5

NiAlRn INTERMEDIATE LAYER(中間層)

FILM THICKNESS OF THE INTERMEDIATE LAYER(中間層膜厚)

STANDARDIZED NOISE(規格化ノイズ)